Structural Controls

Structural water quality control structures are recommended for use with a wide variety of land uses and development types. These controls have demonstrated the ability to effectively treat runoff volume to reduce the amounts of pollutants discharged to the downstream system. Structural storm water quality controls are classified into the following categories:

General Application Controls

General application structural controls are recommended for use in a wide variety of application situations. These structural controls have demonstrated the ability to effectively treat water quality volumes and are presumed to be capable of removing 80 percent of the total suspended solids (TSS) load typically found in urban post-development runoff.

Limited Application Controls

Limited application structural controls are those that are recommended only for limited use for special site or design conditions. Generally, these practices can not alone achieve 80 percent TSS removal goal and are intended for hotspots for specific land use constraints or conditions. Limited application controls may be used within a system of water quality controls and are very effective pre-treatment structures for the General Application Controls. Limited application structural controls should be designed and used only in development situations where regular maintenance is guaranteed.

Wet Detention Ponds

Description

A wet or permanent pool detention pond is one of the most commonly used BMPs to meet water quality protection requirements. The advantages of permanent pool ponds have over other water quality treatment controls are:

- Ponds are durable and require less maintenance than other applicable water quality controls.
- Ponds required for water quantity control are easily modified to treat storm water runoff for water quality.
- Well designed ponds are effective in treating storm water runoff for water quality control.

Wet storm water detention ponds are classified as being:

- Wet Detention Pond. Wet ponds have a permanent (dead storage) pool of water equal to the water quality volume. Temporary storage (live storage) may be added above the permanent pool elevation for larger flows.
- Wet Extended Pond. A wet extended pond is a wet pond where the water quality volume is split evenly between the permanent pool and extended detention storage provided above the permanent pool. During storm events, water is stored above the permanent pool and released over 24-hours. The design has similar pollutant removal efficiencies as traditional wet ponds, but consumes less space.
- Micropool Extended Pond. The micropool extended pond is a variation of the wet extended detention pond where only a small "micropool" is maintained at the outlet to the pond. The outlet structure is designed to detain the water quality volume for 24-hours. The micropool prevents resuspension of previously settled sediments and prevents clogging of the low flow orifice.

When and Where to Use It

Permanent pool ponds improve storm water quality by detaining storm water runoff for an extended period of time to allow pollutants that are suspended in the runoff to settle out. During any given storm event, runoff enters wet ponds and replaces the "treated" water in the permanent pool that has been detained from the previous storm event. As runoff enters the pond, the velocity is significantly decreased, allowing suspended pollutants to settle out of the runoff. Many pollutant particles suspended in storm water runoff are very small in size, therefore the pond must be designed to provide adequate detention time to allow the smaller particles to settle out.

Design Criteria

The components of wet detention ponds that help increase the pond's pollutant removal efficiency are:

- Permanent wet pool
- Temporary pool or overlaying zone
- Aquatic bench
- Forebay
- Flow length
- Low flow orifice
- Emergency spillway.

Permanent Wet Pool

A permanent wet pool is the design feature with the single greatest effect on water quality. Permanent pools have the following design requirements:

- For Wet Detention Ponds, the design permanent pool volume is equal to 1-inch of runoff per impervious acre on the site to reliably achieve moderate to high removal rates of storm water pollutants.
- For Wet Extended Ponds with an Aquatic Bench, the design permanent pool is equal to ½- inches of runoff per impervious acre on the site to reliably achieve moderate to high removal rates of storm water pollutants.
- For Micropool Extended Ponds, the design permanent pool volume is equal to 0.1-inches of runoff per impervious acre on the site to reliably achieve moderate to high removal rates of storm water pollutants.
- An average pool depth of 4 to 6 feet is optimal for water quality treatment. The depth of the permanent pool prevents particles that have settled to the pond bottom from re-suspending when runoff enters the pond.

Temporary Pool

The temporary pool is the designed storage above the permanent pool that controls the designed water quality volume. Consider storm water quantity management when designing the temporary pool volume. To increase the detention time of the runoff, the temporary pool is slowly released through a low flow orifice.

Aquatic Bench

Aquatic vegetation can play an important role in pollutant removal in a storm water pond. Vegetation can enhance the appearance of the pond and stabilize side slopes. The selection of the proper plant species and planting locations is an integral part in designing a successful aquatic bench in the wet detention pond. Prepare a planting plan by a qualified landscape architect or wetland ecologist for the aquatic bench.

Forebay

Provide a forebay for all inlets to a wet water quality pond and place the forebay upstream of the main wet pond area. Design the forebay to trap the majority of the coarse fractions of the suspended solids in the runoff before it enters the main wet pond area. The forebay is separated from the larger wet detention pond area by barriers or baffles that may be constructed of earth, stones, riprap, gabions, or geotextiles. Design the top of the forebay barrier ranging from foot below the normal pool elevation up to an elevation above the permanent pool. A forebay may be designed using manufactured treatment devices.

Flow Length

Optimizing the wet pond flow shape and flow distance through the pond promotes better water quality treatment. For maximum water quality benefits, design the ratio of flow length to flow width in the wet pond at least 3L:1W. Due to site constraints, the minimum allowable design ratio of flow length to flow width is 1.5L:1W. To increase the pond's flow length, the pond may be configured with baffles.

Low Flow Orifice

Design a low flow orifice to slowly release the water quality volume over a period of 24-hours or longer depending upon the design criteria for the water quality structure. These structures are prone to becoming clogged. Protect the low flow orifice from clogging by designing appropriate trash guards. Acceptable trash guards include:

- Hoods that extend at least 6-inches below the permanent pool water surface elevation.
- Reverse flow pipes where the outlet structure inlet is located below the permanent pool water surface elevation.
- Trash boxes made of sturdy wire mesh.

Emergency Spillway

Design emergency spillways to safely pass the post-development 100-year 24-hour storm event without overtopping any dam structures. Design the 100-year water surface elevation a minimum of 1-foot below the top of the embankment.

Inspection and Maintenance:

Regular inspection and maintenance is critical to the effective operation of storm water ponds as designed. Maintenance responsibility for a pond and its buffer should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval. The agreement may contain but is not limited to the following items:

- Mow side slopes of the pond monthly.
- Since decomposing vegetation captured in the wet pond can release pollutants, especially nutrients, it may be necessary to harvest dead vegetation annually. Otherwise the decaying vegetation can export pollutants out of the pond and also can cause nuisance conditions to occur.
- Clear debris from all inlet and outlet structures monthly.
- Repair all eroded or undercut areas as needed.
- Place a sediment marker in the forebay to determine when sediment removal is required.
- Monitor sediment accumulations in the main pond area and remove sediment when the permanent pool volume has been significantly filled and/or the pond becomes eutrophic.

Average Pollutant Removal Capability

Total Suspended Solids:	65-80%	Metals:	35-75%
Copper:	40-65%	Lead:	60-85%
Zinc:	50-75%	Total Phosphorus:	50-70%
Total Nitrogen:	30-45%	Pathogens/Bacteria:	45-75%

Wet Pond

Wet Pond

Summary of Maintenance Requirements

Required Maintenance	Frequency
Clean and remove debris from inlet and outlet structures.	Monthly, or after large storm events
Mow side slopes.	Monthly, or as needed
Removal of invasive vegetation.	Semi-annual
Inspect for damage to control structure.	Annual
Inspect sediment accumulation in the facility and forebay.	Annual
Inspect for operational inlet and outlet structures.	Annual
Repair embankment, side slopes, undercut or eroded areas.	Annual, or as needed
Perform wetland plant management and harvesting.	Annual
Remove sediment from the forebay.	Per design cycle, as needed, after 50% of total forebay capacity is filled
Remove sediment accumulations in the main permanent pool.	5 to 10 year cycle, after 25% of the permanent pool volume is filled

Dry Detention Ponds

Description

A dry (extended) detention pond provides temporary storage of storm water runoff. Dry ponds have an outlet structure that detains runoff inflows and promotes the settlement of pollutants. Unlike wet ponds, dry detention ponds do not have a permanent pool.

A dry pond is designed as a multistage facility that provides runoff storage and attenuation for both storm water quality and quantity. Design dry detention ponds as either single-stage or two-stage. Single-stage ponds are normally used strictly for flood control and are not recommended for water quality benefits. A two-stage pond contains a water quality volume in the lower stage, and has an upper stage for detention of larger storms for flood control.

The lower stages of a dry pond are controlled by outlets designed to detain the storm water runoff for the water quality volume for a minimum duration of 24-hours, which allow sediment particles and associated pollutants to settle out. Higher stages in the pond detain the peak rates of runoff from larger storms for flood and erosion control. Dry detention ponds are designed for complete drawdown of runoff and normally remain dry between storm events.

When and Where to Use It

Apply dry detention ponds to new or existing developments. Dry ponds are considered permanent, year-round control measures. Use dry detention ponds at sites where significant increases in runoff are expected from site development. Use dry detention ponds for residential, commercial, or industrial development sites.

Do not use dry ponds in areas with a high water table. A permanently wet bottom is a mosquito breeding ground.

While dry extended detention ponds are widely applicable, they have some limitations that may make other storm water management options preferable. Dry pond limitations include:

- Possible nuisance due to mosquito breeding.
- While wet ponds can increase property values, dry ponds may detract from the value of a home.
- Dry detention ponds have only moderate pollutant removal when compared to other structural storm water practices, and have limited effectiveness in removing both particulate and soluble pollutants.

Design Criteria

Items to incorporate in dry pond design are: pretreatment, pond shape, pond volume, low flow channel, outfall, emergency spillway, and anti-seep collar.

- Ponds shall be designed for the 2 and 10-year storms
- The 10-year storm should not pass through the emergency spillway
- A minimum 6-inch freeboard between the 10-year water surface and emergency spillway is required
- The 100-year storm should not overtop the embankment

Pretreatment

Pretreatment extends the functional life and increases the pollutant removal capability of dry ponds. Pretreatment reduces incoming velocities and captures coarser sediments, trash, and debris, extending the life of the pond and reduce the frequency of long-term maintenance requirements.

Pretreatment is accomplished with vegetative filters, forebays, or manufactured treatment devices. Size the pretreatment to capture and hold the sediment volume expected between scheduled maintenance clean-outs.

Pond Shape

Design dry ponds with a high length to width ratio and incorporate other design features to maximize the flow path effectively increases the detention time in the system by eliminating the potential of flow to short circuit the pond. A dry pond relies on the process of sedimentation for removal of runoff pollutants. Therefore, design the pond to maximize the degree of sedimentation. Design flow path lengths with long, narrow pond configurations with length to width ratios of 2:1. Ponds that are shallow and have larger surface area to depth ratios provide better pollutant removal efficiencies than smaller, deeper ponds. Designing ponds with relatively flat side slopes also helps to lengthen the effective flow path.

Do not design dry pond inside side slopes should not be more than 2H:1V. The recommended inside pond slopes is 3H:1V with a 2H:1V maximum.

The pond floor should have a minimum slope of 0.5% toward the outlet or underdrain system. The recommended slope is 2.0% to ensure that the pond fully drains between storm events.

Provide adequate maintenance access for all dry detention ponds.

Pond Volume

Dry detention ponds are sized to temporarily store the runoff volume to provide normal peak flow reduction (reduce the post-development peak flow of the design storm event to the pre-development rate). Routing calculations must be used to demonstrate that the storage volume is adequate.

A properly designed dry pond will accumulate sediment over time, leading to the loss of detention volume, runoff quality control and quantity control. An increase in a dry detention pond's maximum design storm storage volume should be considered to compensate for this expected loss of storage volume.

Low Flow Channel

A low flow channel is recommended to prevent standing water conditions. Protect this channel with a TRM or other stabilization method to prevent scouring. Design the remainder of the pond to drain toward this channel. Where recreational uses are desired, design the low-flow channel to one side instead in the middle of the pond.

Outfall

Size the outlet structure for water quality control and water quantity control (based upon hydrologic routing calculations.) The outlet may consist of a weir, orifice, outlet pipe, combination outlet, or other acceptable control structure.

Provide a low flow orifice capable of releasing the water quality volume over 24 hours. The water quality orifice has a minimum diameter of 2-inches and is adequately protected from clogging by an acceptable external trash rack.

Stabilize the outfall of dry ponds to prevent scour and erosion. If the pond discharges to a channel with dry weather flow, care should be taken to minimize tree clearing along the downstream channel, and to reestablish a forested riparian zone in the shortest possible distance.

Emergency Spillway

Design an emergency spillway to pass the 100-year storm event. The spillway prevents pond water levels from overtopping the embankment and causing structural damage. Design the spillway to protect against erosion problems.

Anti-seep Collars

Provide seepage control or anti-seep collars for all outlet pipes.

Inspection and Maintenance

A Pond Maintenance Plan/Agreement is required before approval.

Regular inspection and maintenance is critical to the effective operation of dry ponds as designed. Maintenance responsibility for a pond should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

Conduct inspections semi-annually and after significant storm events to identify potential problems early. Direct maintenance efforts toward vegetation management and basic housekeeping practices such as removal of debris accumulations and vegetation management to ensure that the pond dewaters completely to prevent mosquito and other habitats.

Average Pollutant Removal Capability

Total Suspended Solids:	45%-68%	Metals:	26%-54%
Copper:	15%-38%	Lead:	31%-67%
Zinc:	15%-45%	Total Phosphorus:	14%-25%
Total Nitrogen:	19%-29%	Pathogens/Bacteria:	20%-50%

Dry Pond

Dry Pond

Summary of Maintenance Requirements

Required Maintenance	Frequency
Note erosion of pond banks or bottom	Semi-Annual Inspection
Inspect for damage to the embankment Monitor for sediment accumulation in the facility and forebay. Ensure that inlet and outlet devices are free of debris and operational	Annual Inspection
Repair undercut or eroded areas Mow side slopes Pesticide/ Nutrient management Litter/ Debris Removal	Standard Maintenance
Seed or sod to restore dead or damaged ground cover.	Annual Maintenance (As needed)
Removal of sediment form the forebay	5 to 7 year Maintenance
Monitor sediment accumulations, and remove sediment when the pond volume has been reduced by 25%.	25 to 50 year Maintenance
Repair undercut or eroded areas Mow side slopes Pesticide/ Nutrient management Litter/ Debris Removal	Standard Maintenance

Underground Detention Systems

Description

Detention tanks and vaults are underground structures used to attenuate peak storm water flows through detention or extended detention of storm water runoff. They are constructed out of concrete pipe (RCP), corrugated metal pipe (CMP), High Density Polyethylene Pipe (HDPE) or concrete vaults. The design and material selections considers the potential loading from vehicles on the vault or pipe.

When and Where to Use It

Due to the costs associated with underground detention systems for construction and maintenance, these systems are used when space is limited and there are no other practical alternatives.

In the ultra-urban environment, costs for developable land may be high enough that these systems become a feasible alternative.

Relatively expensive to construct, use concrete vaults in areas where system replacement costs are high.

Less expensive, use CMP or HDPE systems to control significant volumes of runoff in parking lots, adjacent to rights-of-way, and in medians, where they is replaced or maintained if necessary.

Design Criteria

Locate underground detention systems downstream of other structural storm water controls providing treatment of the water quality volume.

The maximum contributing drainage area to be served by a single underground detention vault or tank is 25-acres.

Size underground detention systems to mitigate flows from the 2- and 10 –year design storm event and up. Design the systems to meet detention and water quality requirements set forth in local and state regulations.

Use routing calculations to demonstrate that the storage volume is adequate.

Inspection and Maintenance

- Design the system for easy access for inspection and maintenance.
- Remove any trash/debris and sediment buildup in the underground vaults or tanks annually by pumping them out.
- Perform structural repairs to inlet and outlets as needed based on inspections.

Average Pollutant Removal Capability

Total Suspended Solids:	50%-85%	Metals:	NA
Copper:	35%-70%	Lead:	50%-90%
Zinc:	35%-90%	Total Phosphorus:	55%-70%
Total Nitrogen:	35%-55%	Pathogens/Bacteria:	10%-60%

CMP Underground Detention

HDPE Underground Detention

Storm Water Wetlands

Description

Storm water wetlands remove pollutants primarily through physical filtration and settling, by biological processes of wetland plants, and bacteria in substrates. The storm water wetland is similar in design to the wet pond but has significant vegetation differences. The major difference in the wetland design is the creation of varying depth zones in the shallow marsh area of the wetland to support emergent wetland vegetation. Because consideration must be paid to creating various depth zones and establishing a plant community that can survive in the different zones, the design, construction, and maintenance of storm water wetlands is more complex than wet ponds. There are several different wetland applications including:

- Storm Water Wetland. Constructed shallow marsh system that is designed to treat both urban storm water runoff and control runoff volume. As storm water runoff flows through the wetland, pollutant removal is achieved through settling and uptake by marsh vegetation.
- Shallow Wetland. Most of the water quality treatment takes place in the shallow high marsh or low marsh depths. The only deep sections of the wetland are the forebay and the micropool at the outlet. A disadvantage of shallow wetlands is that a relatively large amount of land is required to store the desired water quality volume.
- Extended Detention Shallow Wetland. This design is similar to the shallow wetland, but part of the water quality treatment volume is provided as extended detention above the surface of the marsh and is released over a period of 24-hours. This application can treat a greater volume of storm water in a smaller space than the shallow wetland design. Plants that can tolerate both wet and dry periods are required in the extended detention area.
- Pond/Wetland System. The system has two separate cells, a wet pond and a shallow marsh. The wet pond is designed to trap sediment and reduce runoff velocities before the runoff enters the shallow marsh. The primary water quality benefits are achieved in the shallow wetland. Less land is required for the pond/wetland system than the shallow wetland and the extended detention shallow wetland.
- Pocket Wetland. A pocket wetland is intended for smaller drainage areas of 5 to 10 acres, and requires excavation down to the water table for a reliable source of water to support the wetland vegetation.

Design Criteria

Do not convert natural wetlands to storm water wetlands. Do not remove natural wetland soils and vegetation to provide a "seedbank" for a constructed storm water wetland without the regulating approval from the US Army Corps of Engineers by obtaining a Section 404 permit. Water quantity storage can be incorporated into the vegetated wetland if the vegetation selected can withstand being submerged for the depth and duration of the water quantity storage time.

Design the wetland with a minimum 2:1 length to width ratio, with 3:1 being the preferred ratio. Maximize the distance between the storm water wetland inlet and outlet to increase the flow length. The flowpath within the wetland is increased through the use of internal berms and shelves used to create the desired varying depth zones within the wetland.

Creating varying depth zones within the wetland increases the pollutant removal efficiency. These depth zones are classified as deep-water zones, which consist of the forebay and outlet micropool, and the shallow water zone that consists of the high marsh, and low marsh area of the wetland. Designing the wetland with varying depth zones prevents the wetland from being taken over by a dominant plant species such as cattails.

Shallow Water Zones

The shallow water zone is defined as being the zones within the constructed storm water wetland that have water depths ranging from 0 to 18 inches. The shallow water zone is designed to promote the growth of emergent wetland plantings and variations in depth allow for a diversity species to survive. Design a level bottom elevation across the width of a wetland cross-section to promote sheet flow and prevent short circuiting or the creation of stagnate dead areas.

High Marsh

Design one-half (½) of the total shallow water zone as high marsh. This zone extends up from 6-inches below the permanent pool water level (6-inches deep). This zone supports a greater density and diversity of wetland species than the low marsh zone.

Low Marsh

Design one-half (½) of the total shallow water zone as low marsh. This zone extends from a depth of 18- to 6-inches below the permanent pool water level. This zone is suitable for the growth of several emergent wetland plant species.

Deep Water Zones

The deep water zones ranges from a depth of 1.5- to 6-feet and includes the forebay, low flow channels, and the outlet micropool. This zone supports little emergent wetland vegetation, but may support submerged or floating vegetation.

Forebay

Design the forebay to reduce the incoming velocities into the wetland. The forebay provides initial settling for sediments, minimizing the amount of suspended sediments that enter the constructed wetland area. Design the forebay as a level spreader distributing the flow evenly and equally across the width of the wetland area. Construct the forebay of an earthen berm no lower than the normal permanent pool depth. Design all inlets to the constructed storm water wetland to discharge to the forebay, and be protected with a properly designed Turf Reinforcement Mat.

Low Flow Channels

A minimum dry weather flowpath is required from the inlet to the outlet for storm water wetlands.

Outlet Micropool.

Design an outlet micropool allowing adequate depth for the extended detention outlet to function properly. Design a drain in the outlet micropool to drain the wetland when needed. Design the outlet micropool 4- to 6-feet deep.

Semi-Wet Zones

The semi-wet zones includes the areas above the permanent pool that will be submerged during larger storm events. This zone supports vegetation that can survive during flooding.

Wetland Planting Plan

Design a wetland planting plan and submit it as part of all constructed wetland design submittals. The selection of the proper plant species and planting locations is an integral part in designing a successful storm water wetland. Have a qualified landscape architect or wetland ecologist prepare a wetland planting plan.

Water Quality Treatment Orifice

Design a low flow orifice to slowly release the water quality volume over a period of 24-hours. Place additional orifice at outlet structures above the temporary water quality pool to provide water quantity control. Protect the water quality orifice from clogging by incorporating an appropriate trash guard.
Select a durable trash guard that extends at least 6-inches below the normal pool surface of the wetland.

Acceptable trash guards include:

- Hoods that extend 6-inches below the permanent pool water surface elevation.
- Reverse flow pipes where the outlet structure inlet is located 6-inches below the permanent pool water surface elevation.
- Trash boxes made of sturdy wire mesh.

Principle Spillway

Design the principle spillway of the constructed storm water wetland to safely pass the 2- and 10-year 24-hour storm event. Equip the spillway with a trash rack.

Emergency Spillway

Design the emergency spillway of the constructed storm water wetland to safely convey discharges resulting from the 100-year 24-hour storm event. Design the 100-year water surface elevation a minimum of 1-foot below the top of the embankment. The emergency spillway may be incorporated into the principle spillway where accommodating the emergency spillway elsewhere is not feasible for the given site characteristics.

Inspection and Maintenance

Regular inspection and maintenance is critical to the effective operation of storm water wetlands. Maintenance responsibility for the constructed storm water wetland should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

- Maintenance requirements for constructed wetlands are particularly high while vegetation is being established. Monitoring during the first year is critical to the success of the wetland.
- Monitor wetlands after all storm events greater than 2-inches of rainfall during the first year to assess erosion, flow channelization and sediment accumulation. Inspection should be made at least once every six months during the first three years of establishment.
- Place a sediment cleanout stake in the forebay area to determine when sediment removal is required.
- Debris should be removed from the inlet and outlet structures monthly.
- Monitor wetland vegetation and replaced as necessary once every 6-months during the first three years of establishment.
- Annually inspect and maintain the depth of the zones within the wetland.
- Annually remove invasive vegetation.
- Repair all eroded or undercut areas as needed.

Average Pollutant Removal Capability

Total Suspended Solids:	66%-78%	Metals:	14%-72%
Copper:	29%-50%	Lead:	62%-76%
Zinc:	32%-52%	Total Phosphorus:	42%-53%
Total Nitrogen:	28%-39%	Pathogens/Bacteria:	58%-78%
Hydrocarbons:	80%		

Storm Water Wetland

Summary of Maintenance Requirements

Required Maintenance	Frequency
Replace wetland vegetation to maintain at least 50% surface area coverage in wetland plants.	Once every 6-months during the first three years of establishment
Clean and remove debris from inlet and outlet structures.	Frequently (3 to 4 times/year)
Mow side slopes.	Frequently (3 to 4 times/year)
Monitor wetland vegetation and perform replacement planting as necessary.	Semi-annual (every 6-months)
Examine stability of the original depth zones.	Annual
Inspect for invasive vegetation, and remove where possible.	Annual
Inspect for damage to the embankment and inlet/outlet structures.	Annual, repair as necessary
Monitor for sediment accumulation in the facility and forebay.	Annual
Inspect for operational inlet and outlet structures.	Annual
Repair undercut or eroded areas.	As needed
Harvest wetland plants that have been “choked out” by sediment buildup.	Annual
Removal of sediment from the forebay.	Per design cycle, as needed, after 50% of total forebay capacity is filled
Remove sediment accumulations in the main permanent pool.	5 to 10 year cycle, after 25% of the permanent pool volume is filled

Bioretention Areas

Description

Bioretention areas are designed to mimic natural forest ecosystems with a combination of soil filtration and plant uptake by utilizing a planting soil layer, mulch, plantings, and an underdrain system. Bioretention areas appear as landscaped or natural areas giving this BMP an appealing image. Storm water runoff enters the Bioretention area and is temporarily stored in a shallow pond on top of the mulch layer. The ponded water then slowly filters down through the planting soil mix and is absorbed by the plantings. As the excess water filters through the system it is temporarily stored and collected by an underdrain system that eventually discharges to a designed storm conveyance system.

When and Where to Use It

Bioretention areas are applicable for small sites where storm water runoff rates are low and typically are received into the Bioretention area as sheet flow. Bioretention drainage areas range from 1-2 acres and are well stabilized to prevent excessive debris and sediment from collecting in the Bioretention area. Because Bioretention areas are sensitive to fine sediments, they are not be placed on sites where the contributing area is not completely stabilized or is periodically being disturbed. Applicable sites include:

- Parking lots,
- Individual residential home sites, and
- Small commercial facilities.

Design Criteria

Bioretention areas work best when constructed off-line, capturing only the water quality volume. Divert excess runoff away from Bioretention areas or collect it with an overflow catch basin. Design Bioretention areas to fit around natural topography and complement the surrounding landscape. Design Bioretention areas with any reasonable shape that fits around sensitive areas, natural vegetation, roads, driveways, and parking lots. The minimum width of Bioretention areas is 10 feet in order to establish a strong healthy stand of vegetation.

Surface Area

The Bioretention surface area may be calculated by the following equation from research by the North Carolina Extension Service, 1999:

$$\mathrm{BSA} = \frac{(\mathrm{DA})(Rv)}{D_{avg}}$$

Where:

BSA	=	Bioretention surface area (feet^2)
DA	=	Contributing drainage area of Bioretention area (feet^2)
R_v	=	Runoff volume (feet) 0.083-feet (1-inch) for SCDHEC
D_{avg}	=	Average ponding water depth above ground (feet)

The Bioretention surface area may also be calculated by the following equation from research by Prince George's County, MD:

$$\text{BSA} = 0.1(Rv)(DA)$$

Where:

BSA	=	Bioretention surface area (feet^2)
0.1	=	Empirical conversion factor
R_v	=	Runoff volume (inches) 1-inch for SCDHEC
DA	=	Contributing drainage area of Bioretention area (feet^2)

Pre-treatment

Pre-treatment of storm water runoff is required to reduce the incoming velocities, evenly spread the flow over the entire Bioretention area, and provide for removal of coarse sediments. The pre-treatment may consist of the following:

- Gravel, landscape stone, or geotextile level spreader located along the upstream edge of the Bioretention area.
- Gently sloping vegetated filter areas along the upstream edge of the Bioretention area.
- Vegetated swale along the upstream edge of the Bioretention area.

The level spreader option is the most desirable because level spreaders successfully reduce incoming energy from the runoff and convert concentrated flow to sheet flow that is evenly distributed across the entire Bioretention area.

Planting Mix

Install the planting mix of the Bioretention area at level grade (0%) to allow uniform ponding over the entire area. The maximum ponding depth should be set at 6-inches to 12-inches to allow the cell to drain within a reasonable time and to prevent long periods of submerging the plantings. The planting mix provides a medium for physical filtration for the storm water runoff plus a source of water and nutrients for plant life. Select a soil mixture with a minimum hydraulic conductivity or permeability of 0.5 in/hour. The planting mix has a significant amount of organic content to support plant life. The average porosity of the planting mix is 0.45.

The planting mix is approximately 60-75 percent sand, 25 percent silt or topsoil, and 10 percent organic or leaf compost. The maximum clay content is less than 5 percent. The minimum depth of the planting mix is based on the following:

- 1.5-foot Bioretention areas utilizing grass as the only vegetative media,
- 3.0-feet for Bioretention areas that utilize shrubs, and
- 4.0-feet for Bioretention areas that utilize trees.

Mulch Layer

The mulch layer provides an environment for plant growth by reducing erosion of the filter bed, maintaining soil moisture, trapping fine sediments, and promoting the decomposition of organic matter. The mulch layer plays an important role in pollutant removal. Liberally apply shredded hardwood mulch 2- to 3-inches deep. Shredded hardwood mulch is the mulch of choice because it resists floatation better than other landscape covers. Pine needles are also applicable for certain situations. Avoid pine bark mulch due to its ability to float.

Water Draw Down Time

The under drain system is designed using the draw down time. The general equation used to determine draw down time is Darcy's Equation:

$$Q = 2.3e^{-5}\ \mathrm{K}\ \mathrm{A}\frac{\Delta \mathrm{H}}{\Delta L}$$

Where:

Q	=	Flow rate through Bioretention (cfs)
K	=	Hydraulic conductivity of the planting mix (in/hr) This value will vary based on the actual planting mix used
A	=	Surface area of Bioretention (feet^2)
ΔH	=	Maximum ponding depth above bottom of soil mix (feet)
ΔL	=	Depth of soil mix (feet)

General Hydraulic Conductivity of Soils

Determining the total draw down time is a three-step process.

1. Determine the time it takes to drain the ponded water.
- Utilize Darcy's Equation to calculate the flow rate (cfs).
- Calculate the total ponded water volume (feet^3) by multiplying the Bioretention area (feet^2) by the ponded water depth (feet).
- Divide the total ponded water volume (feet^3) by the flow rate (cfs) to calculate the time to drain the ponded water (seconds)

2. Determine the time it takes to drain the saturated planting mix.
- Calculate the total volume of water contained in the planting mix (feet^3) by multiplying the Bioretention area (feet^2) by the planting mix depth (feet) by the porosity (dimensionless) of the planting mix.
- Divide the planting mix water volume (feet^3) by the flow rate from Darcy's Equation (cfs) to calculate the time to drain the ponded water (seconds).

3. Add up the time to drain the ponded water with the time that it takes to drain the planting mix to calculate the total Bioretention area draw down time.

Under Drain System

Many of the native soils found in South Carolina do not allow for adequate infiltration. Therefore, all Bioretention cells require an under drain system placed beneath the planting mix.

The under drain system consists of a minimum 4-inch diameter perforated PVC pipe (AASHTO M 252), an 8-inch minimum gravel jacket filter layer, and non-woven geotextiles to separate the piping from the native soils and the gravel from the planting mixture. Design the under drain system to safely pass the peak draw down rate calculated.

Select perforated, continuous closed-joint conduits of corrugated plastic pipe, placed on top of an underlying geotextile fabric. The longitudinal slope of the drain pipe is a minimum of 0.5 percent. The perforated drain pipe may be connected to a structural storm water conveyance system or receiving natural water system.

Place filter gravel around the drainage pipe at a minimum depth of 8-inches. Place a geotextile between the boundary of the gravel and the planting mix to prohibit the planting mix from filtering down to the perforated drain pipe.

Several non-perforated PVC pipes should vertically connect to the under drain pipe and extend to the surface of the planting mix to provide access to clean out the perforated drainage pipe.

Overflow System

Design an overflow system to pass runoff volumes greater than the water quality volume away from the Bioretention area. If the Bioretention area collects sheet flow from a parking area, design a catch basin at the elevation of the maximum 6-inch to 12-inch ponding depth of the Bioretention area to carry the excess runoff from the Bioretention area to the storm sewer system or receiving natural water system.

Planting Plan

A Bioretention landscape plan includes all vegetation types, total number of each species, and the location of each species. A description of the contractor's responsibilities including a planting schedule, installation specifications, initial maintenance, a warranty period, and expectations of plant survival. Include long-term inspection and maintenance guidelines in the planting plan. Have a qualified landscape architect, botanist or qualified extension agent prepare the planting plan.

Inspection and Maintenance

Regular inspection and maintenance is critical to the effective operation of Bioretention areas as designed. Maintenance responsibility of the Bioretention area should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

The surface of the ponding area may become clogged with fine sediments over time. Core aeration or cultivating unvegetated areas may be required to ensure adequate filtration. Other required maintenance includes but is not limited to:

- Conduct pruning and weeding to maintain appearance as needed.
- Replace or replenish mulch as needed.
- Remove trash and debris as needed.

Average Pollutant Removal Capability

Total Suspended Solids:	50%-85%	Metals	NA
Total Phosphorus:	55%-70%	Lead:	50%-90%
Pathogens/Bacteria:	10%-60%	Copper:	35%-70%
Total Nitrogen:	35%-55%	Zinc:	35%-90%

Bioretention Area with uncut clean outs

Summary of Maintenance Requirements

Required Maintenance	Frequency
Pruning and weeding.	As needed
Remove trash and debris.	As needed
Inspect inflow points for clogging. Remove any sediment.	Semi-annual (every 6-months)
Repair eroded areas. Re-seed or sod as necessary.	Semi-annual (every 6-months)
Mulch void areas.	Semi-annual (every 6-months)
Inspect trees and shrubs to evaluate their health.	Semi-annual (every 6-months)
Remove and replace dead or severely diseased vegetation.	Semi-annual (every 6-months)
Removal of evasive vegetation.	Semi-annual (every 6-months)
Nutrient and pesticide management.	Annual, or as needed
Water vegetation, shrubs, and trees.	Semi-annual (every 6-months)
Remove mulch, reapply new layer.	Annual
Test planting mix for pH.	Annual
Apply lime if pH < 5.2.	As needed
Add iron sulfate + sulfur if pH > 8.0.	As needed
Place fresh mulch over entire area.	As needed
Replace pea gravel diaphragm.	Every 2 to 3 years if needed

Infiltration Trenches

Description

Infiltration trenches are excavations typically filled with stone to create an underground reservoir for storm water runoff. The runoff volume gradually exfiltrates through the bottom and sides of the trench into the subsoil over a maximum period of 72 hours (three days), and eventually reaches the water table. By diverting storm water runoff into the soil, an infiltration trench not only treats the water quality volume, but it also preserves the natural water balance by recharging groundwater and preserving channel baseflow. Using natural filtering properties, infiltration trenches remove a wide variety of pollutants from the runoff through adsorption, precipitation, filtering, and bacterial and chemical degradation.

When and Where to Use It

Infiltration trenches are limited to areas with highly porous soils where the water table and or bedrock are located well below the trench bottom. They are only applicable for Hydrologic Soil Group A soils, or soils that have a minimum infiltration rate of 0.3-inches per hour. Infiltration trenches are not intended to trap sediment and are designed with a sediment forebay or other pre-treatment measure to prevent clogging in the gravel. Infiltration trenches are used for medium- to high- density residential, commercial, and institutional developments. They are most applicable for impervious areas where there are low levels of fine particulates in the runoff and the site is completely stabilized and the potential for possible sediment loads is very low. Do not use Infiltration trenches for manufacturing and industrial sites where there is potential for high concentrations of soluble pollutants and heavy metals. Infiltration trenches are designed to capture sheet flow from a drainage area or function as an off-line device. Due to the relatively narrow shape, infiltration trenches are adapted to many different types of sites and are utilized in retrofit situations. Unlike some water quality BMPs, infiltration trenches can easily fit into margin, perimeter or other unused areas of development sites.

Design Criteria

- The maximum drainage area for any one infiltration trench is five (5) acres.
- Direct runoff from areas draining to infiltration practices thorough stabilized vegetated filters at least 20-feet in length.
- Underlying soils have an infiltration rate of <u>0.3-inches per hour</u> or greater determined from site-specific field soil boring samples.
- Do not place infiltration practices in fill material because piping along the fill-natural ground interface may cause slope failure.
- The area of the infiltration trench is determined from the following equation:

$$A = \frac{V}{\left(nd + \frac{kT}{12}\right)}$$

Where:

A = Surface area of infiltration trench (feet^2)
V = Water Quality volume (1-inch)
n = Porosity of stone in infiltration trench (0.3 to 0.5 depending on stone)
d = Depth of trench (ft)
K = Percolation rate of soil (in/hour)
T = Fill time (hours) (A fill time of 2 hours is recommended for most design calculations).

- Use a conservative porosity value (**n**) of 0.32 in volume calculations unless an aggregate specific value is known.
- Design at least (½)-feet between the bottom of the infiltration trench and the elevation of the seasonally high water table, whether perched or regional.
- Determine the seasonally high water table using on-site soil borings and textural classifications to verify the actual site and seasonal high water table conditions.
- The minimum depth of the excavated trench is 3-feet, the maximum depth is 8-feet, and the trench is lined with a permeable geotextile filter fabric.
- Locate infiltration practices greater than 3-feet deep at least ten feet from basement walls.
- Locate infiltration practices a minimum of 150-feet from any public or private water supply well.
- The maximum width of the infiltration trench is 25-feet.
- The stone fill media consists of 1.0- to 2.5-inch D_{50} crushed stone with 6-inches of pea gravel located on top separated by a permeable geotextile filter fabric. This filter fabric prevents sediment from passing into the stone media, and should be easily separated from the geotextiles that protect the sides of the excavated trench.
- Install a 6-inch sand filter or permeable filter fabric on the bottom of the trench.
- The maximum slope bottom of the infiltration practice is 5 percent.
- Design the infiltration trench to fully de-watered within a 24- to 72-hour period depending on trench dimensions and soil type.
- Install an observation well spaced a maximum of 100-feet. The well is made of 4- to 6-inch PVC pipe. Extend the well to the bottom of the trench. The observation well shows the rate of de-watering after a storm event, and helps predict when maintenance is required. Install the observation well along the centerline of the trench, and flush with the ground elevation of the trench. Cap the top of the well and lock it to discourage vandalism and tampering.

Inspection and Maintenance

Regular inspection and maintenance is critical to the effective operation of infiltration trenches as designed. Maintenance responsibility for the infiltration trench should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of the Storm Water Management Permit approval. Typical maintenance responsibilities include:

- Keep a record of the average de-watering time of the infiltration trench to determine if maintenance is required.
- The top 6-inch layer of pea gravel and geotextile separating the pea gravel from the stone media serve as a sediment barrier and require replacement when full of sediment.
- Clear debris and trash from all inlet and outlet structures monthly.
- Check the observation well after three consecutive days of dry weather after a rainfall event. If complete de-watering is not observed within this period, there may be clogging within the trench requiring proper maintenance.
- Remove trees, shrubs, or invasive vegetation semi-annually.
- If complete failure is observed, perform total rehabilitation by excavating the trench walls to expose clean soil, and replacing the gravel, geotextiles, and topsoil.

Average Pollutant Removal Capability

Total Suspended Solids:	80%-90%	Metals:	70%-85%
Copper:	50%-60%	Lead:	80%-90%
Zinc:	80%-90%	Total Phosphorus:	50%-60%
Total Nitrogen:	35%-55%	Pathogens/Bacteria:	90%-98%
Hydrocarbons:	85%		

Infiltration Trench

Summary of Maintenance Requirements

Required Maintenance	Frequency
Ensure that the contributing area is stabilized with no active erosion.	Monthly
Grass filter strips should be mowed and grass clippings should be removed.	Monthly
Check observation wells after 72 hours of rainfall. Wells should be empty after this time period. If wells have standing water, the underdrain system or outlet may be clogged.	Semi-annual (every 6-months)
Remove evasive vegetation.	Semi-annual (every 6-months)
Inspect pretreatment structures for deposited sediment.	Semi-annual (every 6-months)
Replace pea gravel, topsoil, and top surface filter fabric.	When clogging or surface standing water is observed
Perform total rehabilitation of infiltration trench.	Upon observed failure

Enhanced Dry Swales

Description

Enhanced dry swales are conveyance channels engineered to capture, treat, and release the storm water quality runoff volume from a particular drainage area. Enhanced swales are different from normal drainage swales in that they have a designed structure implemented in them to enhance detention and storm water pollutant removal. Enhanced dry swale systems are designed primarily for storm water quality and have only a limited ability to provide storm water runoff volume control and downstream channel protection. Enhanced dry swales are vegetated channels designed to include a filter bed of prepared soil that overlays an underdrain system. Dry swales are sized to allow the entire water quality storage volume to be filtered or infiltrated through the swale bottom. Because these swales are predominantly dry, they are preferred in residential settings.

When and Where to Use It

Enhanced swales are applicable in moderate to large lot residential developments and industrial areas with low to moderate density where the impervious cover (parking lots and rooftops) of the contributing drainage areas is relatively small. Enhanced swales are also useful along rural roads and highways that have driveway entrances crossing the swale.

Design Criteria

Design enhanced swales with minimal channel slope, forcing the flow to be slow and shallow. This aspect of the enhanced swale allows particulates to settle out of the runoff and limits the effects of erosion. Place berms, check dams, weirs, and other structures perpendicular to the swale flow path to promote settling and infiltration.

- Enhanced swales are open conveyance channels that have a filter bed of permeable soils overlaying an underdrain system. Runoff is detained in the main swale section where it filters through the filter bed. The runoff is then collected and conveyed to the desired outlet through a perforated pipe and gravel system.
- The maximum designed de-watering time is 48 hours, with the recommended de-watering time being 24-hours.
- Enhanced swales have a contributing drainage area less than five (5) acres.
- Design the swale to capture the required water quality runoff volume, and safely pass larger flows. Flow enters the swale through a pretreatment forebay or along the sides of the swale as sheet flow produced by level spreader trenches along the top of the bank.
- Limit swale slopes between 1 and 2 percent, unless site topography dictates larger slopes. In this instance, place drop structures in the swale to limit the slope of a particular section of the swale. Set the spacing between drop structures a minimum of 50-feet. Add energy dissipation techniques on the downstream side of the drop structures.
- The maximum overall depth of the water quality runoff volume detained in the channel is 1.5-feet.
- The bottom width of the swale ranges between 2- and 8-feet where applicable to ensure an adequate filtration area. Wider channels may be designed to increase the filtration area, but consideration must be given to prevent uncontrolled sub-channel formation.
- The maximum side slopes of the swale are 2H:1V, and 4H:1V is recommended for ease of maintenance and for side inflow to remain as sheet flow.
- Design the peak velocity for the 2-year 24-hour storm event to be non-erosive for the soil and vegetation selected for the swale.

Filter Bed

The filter bed for an enhanced dry swale consists of a permeable soil layer at least 2.5-feet deep. The drainage pipe is a minimum 4-inch diameter perforated PVC pipe (AASHTO M 252) in a 6-inch gravel layer. Select a soil media that has a minimum infiltration rate of 1.0-foot per day, and a maximum infiltration rate of 1.5-feet per day. Place a permeable geotextile filter between the gravel and the overlaying permeable soil.

Forebay

Protect flow inlets to an enhanced dry swale forebay to reduce erosive forces of the runoff. The preferable material is a TRM. Riprap may also be used. Provide swale pretreatment with a sediment forebay. The pretreatment volume is equal to 0.1-inches per impervious acre of the drainage area. The forebay is typically provided by designing a check dam at the inlet of the swale.

Outlet Structures

The underdrain system of the enhanced dry swale discharges to the storm drainage system on site, or discharges to a stable protected outlet point.

Overflows

For maximum performance, enhanced dry swales are recommended to be off-line structures. If a swale is designed to be an online structure, it must be able to safely pass the 25-year 24-hour storm event.

Landscape Plan

Design the enhanced dry swale landscape plan to include the type of turf grass species required along with a permanent maintenance guideline. Have the planting plan prepared by a qualified landscape architect, botanist or qualified extension agent.

Inspection and Maintenance

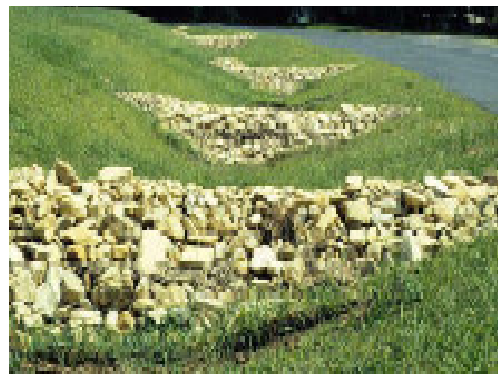
Regular inspection and maintenance is critical to the effective operation of enhanced swales. Maintenance responsibility should be vested with a responsible authority by means of a legally binding and enforceable maintenance agreement that is executed as a condition of plan approval.

The surface of the filter bed may become clogged with fine sediments over time. Light core aeration is required to ensure adequate filtration. Other required maintenance includes but is not limited to:

- Mowing to maintain storage volume and appearance as needed.
- Remove trash and debris as needed.

Average Pollutant Removal Capability

Total Suspended Solids:	70%-80%	Hydrocarbons:	65%
Total Phosphorus:	35%-50%	Lead:	60%-70%
Pathogens/Bacteria:	10%-60%	Copper:	15%-45%
Total Nitrogen:	40%-60%	Zinc:	40%-65%

Enhanced Swales

Summary of Maintenance Requirements

Required Maintenance	Frequency
Mow grass to maintain design height and remove clippings.	As needed (frequent/seasonally)
Nutrient and pesticide management.	Annual, or as needed
Inspect side slopes for erosion and repair.	Annual, or as needed
Inspect channel bottom for erosion and repair.	Annual, or as needed
Remove trash and debris accumulated in forebay.	Annual
Inspect vegetation. Plant an alternative grass species if original cover is not established.	Annual (semi-annually first year)
Inspect for clogging and correct the problem.	Annual
Roto-till or cultivate the surface of the bed if swale does not draw down in 48 hours.	As needed
Remove sediment build-up within the bottom of the swale.	As needed, after 25% of the original design volume has filled

Pre-Fabricated Control Devices

Description

The need for urban water quality BMPs that are very efficient and present less space constraints has produced the industry of innovated storm water BMP technology and products. These pre-manufactured products combine settling, filtration, and various biological processes into one controlled system. By combining these different processes, these BMPs are designed to focus on removing many different types and concentrations pollutants. Even where pre-fabricated control devices are not able to meet the 80 percent TSS removal goal alone, they can provide excellent pre-treatment in a series of water quality control BMPs or inlet to permanent pool detention basins or storm water wetlands.

Post construction pre-fabricated storm water quality BMPs are designed to filter and trap trash, floatable contaminates, sediment, oil and grease, and other pollutants. These BMPs are incorporated into storm water conveyance systems for pretreatment of storm water runoff. In some instances, pre-fabricated storm water quality BMPs serve as the only treatment mechanism before the runoff is discharged. Post construction pre-fabricated storm water quality BMPs are classified in to three separate categories:

1. Catch Basin Inserts
2. Separation Devices
3. Filtration Devices

When and Where to Use It

Pre-fabricated control devices may be used to treat runoff as long as they are designed to treat the first 1-inch of runoff and/or are proven to provide 80 percent TSS removal. Pre-fabricated control devices include the following beneficial attributes for water quality control over conventional water quality BMPs:

- Pre-fabricated control devices are placed almost anywhere on a site where they can receive concentrated flows from storm drainage pipes.
- Pre-fabricated control devises are safe to the public because storm water is treated within the unit and no surfaces are open to the environment, unlike the permanent pool detention pond or storm water wetland.
- Minimal on-site construction is required because pre-fabricated control devices are typically assembled before they reach the site.

Design

Catch Basin Inserts

Catch Basin Inserts are defined as BMPs designed to be installed directly into storm drain catch basins to treat the runoff before it enters the primary conveyance system.

There are three basic Catch Basin Inserts available: tray, bag, and basket. These inlets typically are made of a stainless steel or a high strength corrugated plastic frame that supports a sedimentation chamber and filter media designed to absorb specific pollutants such as oil, grease hydrocarbons, and heavy metals. Catch Basin Inserts sometime include a high flow bypass mechanism to prevent scouring and re-suspension of previously trapped pollutants during larger rainfall events.

Pollutant removal efficiencies are variable and highly dependent on storm frequency, influent pollutant concentrations, rainfall intensity and other factors. Catch Basin Inserts exhibit the following properties:

- Utilize settling, separation, swirling, centrifugal force, and filtering techniques to remove pollutants from storm water runoff.
- Contain no moving components that require an external power source such as electricity, gas powered engines or generators.
- Have posted data from third party test results.

Catch Basin Insert Average Pollutant Removal Capability

Total Suspended Solids:	50%-85%	Metals	NA
Copper:	35%-70%	Lead:	50%-90%
Zinc:	35%-90%	Total Phosphorus:	55%-70%
Total Nitrogen:	35%-55%	Pathogens/Bacteria:	10%-60%

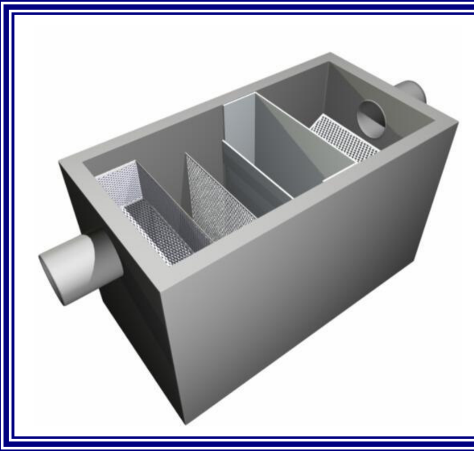
Catch Basin Inserts

Separation Devices

Separation Devices are defined as BMPs designed and sized to capture and treat storm water runoff to prevent pollutants from being transported downstream. Separation Devices contain a sump for sediment deposition and a series of chambers, baffles, and weirs to trap trash, oil, grease and other contaminants. These BMPs are designed as flow-through structures where the inflow rate into the structure is regulated. These structures are not designed to store the entire water quality volume. Separation Devices sometime include a high flow bypass mechanism to prevent scouring and re-suspension of previously trapped pollutants during larger rainfall events.

Pollutant removal efficiencies are variable and are highly dependent on storm size, influent pollutant concentrations, rainfall intensity, and other factors. Separation Devices exhibit the following properties:

- Utilize settling, separation, swirling, and centrifugal force techniques to remove pollutants from storm water runoff.
- Contain no moving components that require an external power source such as electricity, gas powered engines or generators.
- Have posted data from third party test results.

Separation Devices

Filtration Devices

Filtration Devices are defined as BMPs designed and sized to capture and treat storm water runoff to prevent pollutants from being transported downstream. Filtration Devices are used in areas with impaired receiving waters where high pollutant removal efficiencies are required. Filtration Devices usually contain a sedimentation chamber and a filtering chamber. These devices may contain filter materials or vegetation to remove specific pollutants such as nitrogen, phosphorus, copper, lead, or zinc.

Pollutant removal efficiencies are variable and are highly dependent on storm size, influent pollutant concentrations, rainfall intensity and other factors. Filtration Devices shall exhibit the following properties:

- Utilize filtering techniques to remove pollutants from storm water runoff.
- Have posted data from third party test results.

Filtration Device

Separation and Filtration Device Average Pollutant Removal Capability

Total Suspended Solids:	80%	Metals	60%
Copper:	50%	Lead:	60%
Zinc:	70%	Total Phosphorus:	40%
Total Nitrogen:	30%	Hydrocarbons:	80%

Products

There are many pre-fabricated water quality structures on the market that may be used as water quality control BMPs.

Installation

Install in accordance with the Manufacturer's written installation instructions and in compliance with all OSHA, local, state, and federal codes and regulations. A Manufacturer's representative is required to certify the installation of all post construction pre-fabricated storm water quality BMPs.

Proper site stabilization is essential to ensure that post construction pre-fabricated storm water quality BMPs function as designed. These structures are not interned to trap eroded sediment from during construction operations. Post construction pre-fabricated storm water quality BMPs are the last storm water runoff structures installed on-site, or shall remain off-line until final stabilization is achieved.

Inspection and Maintenance

- Inspect and maintain in accordance with the Manufacturer's written recommendations.
- The specific maintenance requirements and schedule prepared by the Manufacturer is signed by the owner/operator of the BMP.
- Require frequent inspection and maintenance to maximize pollutant removal.
- Maintain BMPs at least bi-annually to ensure that the BMPs are working properly.

- Keep a maintenance log to track routine inspections and maintenance. Lack of maintenance is the most common cause of failure for post construction pre-fabricated storm water quality BMPs.
- Remove accumulated sediment and other trapped pollutants when the BMP becomes full. Typical removal of pollutants requires the use of a Vactor truck.

Summary of Maintenance Requirements

Required Maintenance	Frequency
Inspect separation and filtration units.	Regularly (quarterly)
Clean out sediment, oil and grease, and floatables. Manual removal of pollutants may be necessary.	As needed
Perform requirements obtained from manufacturer.	As needed
Inspections.	Frequency of inspection and maintenance is dependent on land use, accumulated solids climatological conditions, and design of pre-fabricated device

Vegetated Filter Strips

Description

Vegetated Filter Strips (VFS) are zones of vegetation where pollutant-laden runoff is introduced as sheet flow. VFS may take the form of grass filters, grass filter strips, buffer strips, vegetated buffer zones, riparian vegetated buffer strips, and constructed filter strips.

When and Where to Use It

Applicable in areas where filters are needed to reduce pollutant impacts to adjacent properties and water bodies. VFS are used to remove pollutants from overland sheet flow but are not effective in removing sediment from concentrated flows. There are two main classifications of VFS:

- Constructed filter strips: Constructed and maintained to allow for overland flow through vegetation that consists of grass-like plants with densities approaching that of tall lawn grasses.
- Natural vegetative strips: Area where pollutant-laden flow is directed in an overland manner, including riparian vegetation around drainage channels. Vegetation ranges from grass-like plants to brush and trees with ground cover.

VFS remove pollutants primarily by three mechanisms:

1. Deposition of bedload material and its attached chemicals as a result of decreased flow velocities and transport capacity. This deposition takes place at the leading edge of the filter strip.
2. Trapping of suspended solids by the vegetation at the soil vegetation interface. When suspended solids settle to the bed, they are trapped by the vegetated litter at the soil surface instead of being re-suspended as would occur in a concentrated flow channel. When the litter becomes inundated with sediment, trapping no longer occurs by this mechanism.
3. Trapping of suspended materials by infiltrating water. This is the primary mechanism by which dispersed clay sized particles are trapped.

VFS effectiveness fluctuates considerably depending on vegetation type, vegetation height and density, season of the year, eroded particle characteristics, size of drainage area, and site topography.

Design Criteria

Select a vegetation type, a ground slope, filter strip width, and strip length. Locate VFS on the contour perpendicular to the general direction of flow. Select vegetation to be dense, turf-forming grass in order to minimize water channelization. Never assume that natural vegetation is adequate for VFS. Design a ponding area at the leading edge of the VFS for bedload deposition.

General Design Requirements

a. Select an applicable area for the VFS
   Minimum Ground Slope = 1 percent
   Maximum Ground Slope = 10 percent
b. Select a vegetation type.
c. Select the design life and maximum allowable sediment deposition. A design life of 10 years and deposition of 0.5-feet is recommended.
d. Estimate the long-term sediment yield entering the filter strip and a 10-year 24-hour design single-storm sediment yield.
e. Determine desired Trapping Efficiency- 80 percent design removal efficiency goal of the total suspended solids (TSS) in the inflow.
f. Estimate the filter length necessary to prevent deposition within the filter greater than 0.5-feet. (Assume filter width is equal to disturbed area width but no smaller than 15-feet.)
g. Use the filter length to calculate Trapping Efficiency for the design storm.
h. Repeat (d) and (e) until the lengths match.

Inspection and Maintenance

- Maintenance is very important for filter strips, particularly in terms of ensuring that flow does not short circuit the practice. They require similar maintenance to other vegetative practices.
- Inspect vegetation for rills and gullies annually and correct. Seed or sod bare areas.
- Inspect grass after installation to ensure it has established. If not replace with an alternative species.
- Inspect to ensure that grass has established annually. If not, replace with an alternative species.
- Mow grass to maintain a height of 3- to 4-inches.
- Remove sediment build-up from the bottom when it has accumulated to 25% of the original capacity.

Average Pollutant Removal Capability

75 feet in length		150 feet in length		Average	
Total Suspended Solids:	54%	TSS:	84%	TSS:	70%
Lead:	16%	Lead:	50%	Metals	40%-50%
Zinc:	47%	Zinc:	47%	Total N:	30%
Total Phosphorus:	- 25%	Total Phosphorus:	-40%	Total P:	10%
Nitrate Nitrogen:	-27%	Nitrate Nitrogen:	-20%	Nitrate Nitrogen:	0%
				Pathogens/Bacteria:	NA

Roadside Vegetated Filter Strip

Summary of Maintenance Requirements

Required Maintenance	Frequency
Mow grass to maintain design height.	Regularly (frequently)
Remove litter and debris.	Regularly (frequently)
Inspect for erosion, rills and gullies, and repair.	Annual, or as needed
Repair sparse vegetation.	Annual, or as needed
Inspect to ensure that grass has established. If not, replace with an alternative species.	Annual, or as needed
Nutrient and pesticide management.	Annual, or as needed
Aeration of soil.	Annual, or as needed

Grass Paving and Porous Paving Surfaces

Description

Grass Paving

Grass paving technology allows for the reduction of paved areas by implementing grass paving in areas that are infrequently used such as fire lanes and overflow parking where applicable. A variety of grass paving materials are available on the market. Grass paving units are designed to carry vehicular loading and may be composed of different types of materials. The pavers are typically covered with sod to make the areas indistinguishable from other grassed areas. Grass pavers allow water quality benefits by allowing storm water to infiltrate into the underlying soils and by the filtering of storm water as it flows through the grass.

Grass pavers provide a more aesthetically pleasing site and reduce the impact of complete asphalt surfaces. Grass pavers should not be used for frequently traveled or parked in areas. Grass pavers reduce the runoff volume and extend the time of concentration for a particular site. Some pavers provide enough infiltration to be considered a pervious area.

Porous Paving

Porous pavement is a permeable pavement surface with an underlying stone reservoir to temporarily store surface runoff before it infiltrates into the subsoil. This porous surface replaces traditional pavement, allowing parking lot storm water to infiltrate directly and receive water quality treatment, and also reducing runoff from the sit

When and Where to Use It

Porous pavement options include porous asphalt, pervious concrete, and grass pavers. The ideal application for porous pavement is to treat low-traffic or overflow parking areas. Porous pavement also has highway applications where it is used as a surface material to reduce hydroplaning.

Porous pavements are a good option in ultra-urban areas because they consume no space since there is very little pervious area in these areas. Since porous pavement is an infiltration practice, do not apply it on storm water hot spots due to the potential for ground water contamination. The best application of porous pavement for retrofits is on individual sites where a parking lot is being resurfaced.

Design Criteria

Take soil boring to a depth of at least 4 feet below bottom of stone reservoir to check for soil permeability, porosity, depth of seasonally high water table, and depth to bedrock.

Not recommended on slopes greater than 5% and best with slopes as flat as possible.

Minimum setback from water supply wells: 100 feet.

Minimum setback from building foundations: 10 feet down gradient, 100 feet upgradient.

Not recommended where wind erosion supplies significant amounts of sediment.

Use on drainage areas less than 15 acres.

Minimum soil infiltration rate of 0.3-0.5 inches per hour.

Typically design for storm water runoff volume produced in the tributary watershed by the 6-month, 24-hour duration storm event.

A typical porous pavement cross-section consists of the following layers:

1) Porous asphalt course 2-4 inches thick,
3) Reservoir course of 1.5 to 3 inch stone,
2) Filter aggregate course, and
4) Filter fabric.

Use a geotextile meeting AASHTO M288 Class 1, 2, or 3 in all cases as a filter to protect the long-term performance of the system.

Inspection and Maintenance

- Porous pavement requires extensive maintenance compared with other practices.
- Avoid sealing or repaving with non-porous materials.
- Ensure that paving area is clean of debris, paving dewaters between storms, and that the area is clean of sediments monthly.
- Mow upland and adjacent areas, and seed bare areas as needed.
- Vacuum sweep frequently to keep the surface free of sediment as needed.
- Inspect the surface for deterioration or spalling annually.
- Perform high pressure hosing to free pores in the top layer from clogging as needed.

Grass Paver

Porous Paving